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COMPRESSION WOOD FORMATION AND OTHER CHARACTERISTICS OF PLANTATION-GROWN PINUS CARIBAEA

BY R. S. BOONE AND M. CHUDNOFF

INSTITUTE OF TROPICAL FORESTRY
RIO PIEDRAS, PUERTO RICO

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RESUMEN

Se tomaron muestras de setenta y un árboles de cuatro plantaciones en dos zonas de vida para determinar la cantidad, orientación, y efecto de la madera de compresión en algunas de las propiedades físicas y mecánicas de *Pinus caribaea* de 8-10 años de edad plantado en Puerto Rico.

La madera de compresión fué encontrada en todos los troncos y la cantidad presente no varía con la altura, pero fué influenciada por una interacción de la inclinación del árbol, velocidad de crecimiento, e inclinación del terreno. La orientación de la madera de compresión aparece ser influenciada por el efecto combinado de la inclinación, aspecto del declive, y vientos prevalecientes. Varios niveles de la madera de compresión no afectan el peso específico, módulo de ruptura, o el trabajo con carga máxima en la prueba de viga. La madera de compresión reduce considerablemente el módulo de elasticidad. La contracción longitudinal aumenta con el aumento de la madera de compresión, tangencial, radial, y la contracción volumétrica disminuye. Las maderas obtenidas de estos árboles fueron secadas al horno sin que les surgieran defectos al secarse y fueron fáciles de trabajar en la maquinaria aunque existían volúmenes altos de madera de compresión.

SUMMARY

Seventy-one trees from four plantations located in two life zones were sampled to determine the amount, orientation, and effect of compression wood on some physical and mechanical properties of 8-10 year old *Pinus caribaea* grown in Puerto Rico.

Compression wood was found in all stems and the amount present did not vary with height, but was influenced by an interaction of tree lean, growth rate, and slope of terrain. Orientation of compression wood appeared to have been influenced by a combined effect of lean, aspect of slope, and prevailing winds. Several levels of compression wood did not affect specific gravity, modulus of rupture, or work to maximum load in beam tests. Compression wood did reduce modulus of elasticity considerably. Longitudinal shrinkage increased with increasing amounts of compression wood; tangential, radial, and volumetric shrinkages decreased. Boards from these trees were kiln dried without seasoning degrade and were easy to machine even though high volumes of compression wood were present.

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COMPRESSION WOOD FORMATION AND OTHER CHARACTERISTICS OF PLANTATION-GROWN *PINUS CARIBAEA*

by

R. S. Boone and M. Chudnoff

Institute of Tropical Foresty, Rio Piedras, Puerto Rico[1/]

INTRODUCTION

Several species of pine are planted on lowland tropical sites. Most promising are some strains of *Pinus caribaea* Morelet established in Australia, South Africa, Trinidad, Surinam, and elsewhere. The potential for high volume production is great (8), but Hughes (6) has indicated concern for the wood quality of rapid-grown tropical conifers. He reports compression wood is common in *P. caribaea* trees cultivated in South Africa, Fiji, and Trinidad and considers this a serious defect that can cause marked degrade in seasoning and reduce yields and strength in pulping. Compression wood is a growth response in stems displaced from their normal vertical position and is characterized by asymmetrical cambial activity. Tracheids are round in outline with numerous intercellular spaces. Zones of this tissue may be differentiated from normal growth by viewing thin, wet cross-sections with transmitted light. Anatomically, compression wood tracheids are marked by striations or checks inclined at a large angle from the vertical in the S_2 layer of the secondary wall. Low (11) and Westing (19) thoroughly review the subject.

Pinus caribaea var. *hondurensis* Barr. and Golf. was successfully established in Puerto Rico once the need for mycorrhizal inoculum was recognized (2). Early thinnings from these plantations showed a high incidence of compression wood formation even in relatively straight trees. Because the presence of compression wood is undesirable for most lumber uses and adversely affects pulp yield and strength, a study was undertaken to measure: 1) the amount and distribution in trees and stands of *P. caribaea* grown in Puerto Rico; 2) the effect of stem lean, growth rate, and slope of terrain on its formation; and 3) its effect on some physical and mechanical properties of wood.

MATERIALS AND METHODS

Trees, 8 to 10 years old, from four test plantings were sampled (Table 1). The Cubuy Plantation is on the western edge of the Luquillo Experimental Forest in a life zone that is Subtropical Wet according to the Holdridge system (5), the Becerra Plantation is in the center of Puerto Rico near Jayuya and is also classified as a Subtropical Wet site; the low elevation Roig Plantation is near Humacao and is located in a Subtropical Moist zone; the small Rio Piedras coastal stand is on the grounds of the University of Puerto Rico Agricultural Experiment Station, a Subtropical Moist site.

1/ In cooperation with the University of Puerto Rico

Tree Selection

Cubuy plantation. – Trees marked for study were clustered in an area of about 1 hectare and were selected for the following attributes:

1. Lean
   a. less than 1 degree
   b. more than 2.5 degrees
2. Growth rate (as reflected by diameter outside bark in this even-aged stand)
   a. d.b.h. less than 15 cm.
   b. d.b.h. more than 20 cm.
3. Topography
   a. level bench (less than 10 percent slope)
   b. steep terrain (30-50 percent slope)

Three trees were selected for each of the 3 factors at 2 levels, or a total of 24 stems. All trees had dominant or co-dominant crowns and d.b.h. of major and minor axes did not differ by more than 2 cm. Slight crook or sweep was acceptable provided an imaginary line could be drawn from the center of the stump to the crown and stay within the bole.

Becerra, Roig, and Rio Piedras plantations. – The small size of these plantations with a limited selection of stems did not permit three-factor experiments as described for Cubuy. However, as far as possible, trees representing extremes of lean, growth rate, and terrain were marked for study. The same limitations for crown class, bole symmetry, and bole straightness were applied.

Selection of Material Within Trees

Cubuy plantation. – After felling, 10 cm. thick cross-sections were cut from the stump end and at 2 m intervals to a top outside bark diameter of 10 cm. Where necessary, cross-sections were shifted so that none was closer than 15 cm below or 5 cm above a branch or branch scar. In addition to the cross-sections, the first and second 2-meter bolt lengths were collected and all scribed in the field to permit reorientation to magnetic north.

Becerra, Roig, and Rio Piedras plantations. – The same procedures were used here except only cross-sections from the butt and 2 m height were taken. No bolts were collected.

Measurement of Compression Wood

Immediately after field collecting, the 10 cm cross-sections were resawn into 3-mm-thick disks and marked to show direction of lean and position in the bole. They were then frozen to prevent deterioration (staining, etc.) during storage. As needed disks were thawed and viewed, using transmitted light, to delineate zones of compression wood (13). No attempt was made to identify "mild" and "severe'. forms. Percent areas of compression wood were

measured using dot-grid overlays. The same disks were viewed by reflected light to note growth ring patterns.

Physical and Mechanical Properties

The second 2-meter bolts collected at Cubuy were sawn to yield 4-5 cm thick cants that boxed the pith. These cants were cut perpendicular to the zones of maximum compression wood formation so that one side of the pith had a high percentage of compression wood and the other little or none. Sticks were ripped from both sides of the pith to yield defect-free (other than compression wood) blanks for beam tests and shrinkage measurements. Radial, tangential, longitudinal, and volumetric shrinkages from the green to oven-dry condition were determined using specimens 1 by 1 by 4 in. suggested by Kelsey and Kingston (7). These specimens had varying levels of compression wood, and were also used for specific gravity determinations. Blanks for beam tests were air dried to 12 percent moisture content, machined to 1 by 1 by 16 in., and static loaded over a 14 in. span following ASTM procedures (1). Center loading, however, was parallel to growth rings. Modulus of rupture, modulus of elasticity, and work to maximum load were calculated.

Seasoning and Machining

Residual material from the second 2-meter bolts and the first 2-meter bolts were flat sawn into 1 in. boards and stickered for air drying. When the moisture content reached 18-20 percent, the boards were kiln dried to a final moisture content of 10 percent using a schedule developed for soft pine (T9-C6) (15). After inspection for drying defects (warp, checks, cross-breaks), the boards were planed and edged with a tongue and groove pattern. Machining characteristics were assessed. A wall was then paneled with the dressed boards to observe their performance in use.

RESULTS AND DISCUSSION

Amount of Compression Wood Within Stems

Percent areas of compression wood at the stump to a 10 m height for the two levels of lean, growth rate, and slope of terrain at the Cubuy Plantation are given in Table 2. Variations with height are slight. Means of all trees combined at each 2 m level range only from 17.6 to 19.9 percent. A linear regression was not significant.

Since percent areas of compression wood did not vary with height in the stem, amounts at the 0, 2, and 4 m level were pooled to determine effects of lean, growth rate, and terrain. Analysis of the three-factor experiment showed that there may be an interaction. Slow growing trees on flat terrain in the high lean category were developing significantly less compression wood (to a height of 4 m) than in the other treatment combinations. No first order interactions were significant. There is previous evidence that compression wood is not purely a result of lean. Low (11) cites cases where straight trees may generate some compression wood. Shelbourne (16) demonstrates that severe compression wood in slash, loblolly, and longleaf pine has a moderately strong positive relationship with straightness, but slight or moderate compression wood shows a negative though weak relationship. Zimmermann (21) describes tension wood occurring in vertical stems of dicotyledons and, thus, not a result of lateral gravitational displacement of auxin. That apparently straight trees can generate as much or more reaction wood as leaning ones suggests, perhaps, stimuli other than geotropic.

In this study, amount of compression wood formed was not related to growth rate. Pillow and Luxford (14), however, found that for loblolly and longleaf pine trees having the same amount of lean, compression wood increased as the rate of diameter growth increased.

Overall amounts of compression wood generated in the four plantations varied. Mean proportions of compression wood at the 2 m level for Cubuy (18.2 percent) was significantly higher than that at Roig (8.1 percent) and Becerra (7.5 percent), but not significantly different from that found at Rio Piedras (15.2 percent). Reasons for these differences are not apparent. Sampling limitations previously described may be a factor. It is important to note, though, that compression wood occurred in all 71 trees from the 4 plantations.

Orientation of Compression Wood Within Stems

Several patterns of compression wood observed in this study are shown in Figure 1. Disks were illuminated by transmitted light. The classical pattern (elliptical cross-section, off-centered pith, massive one-sided concentration of compression wood) was rarely found

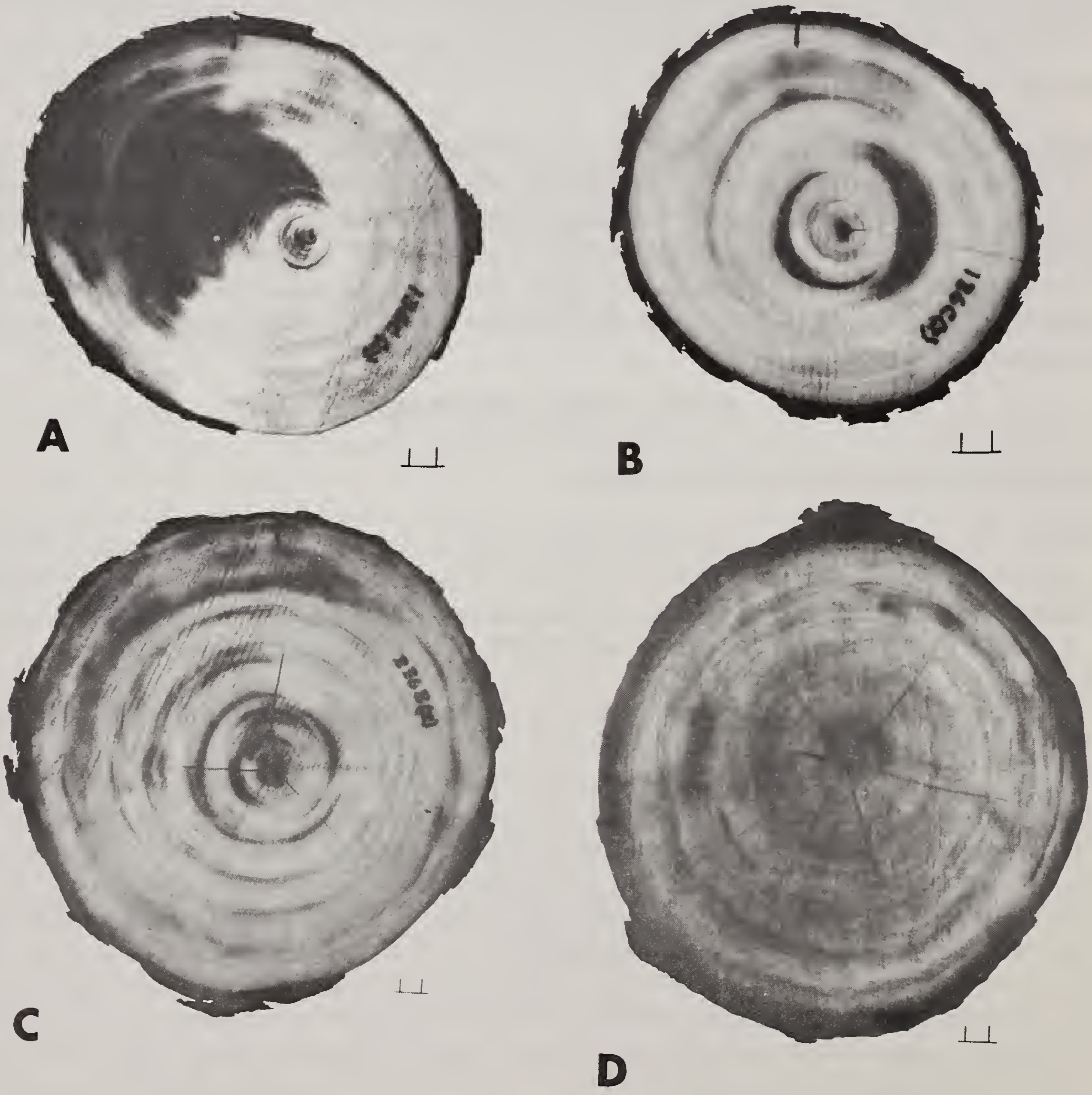

Figure 1. — Compression wood patterns (dark areas) in *Pinus caribaea* as viewed by transmitted light: (A) usual development in eccentric stem; (B) large areas of compression wood on opposite sides of pith; (C) circling streaks of compression wood from pith to bark; (D) disk with almost no compression wood. (Scale: 1 cm.).

(Figure 1A). More common were floating arcs on opposite sides of the pith (Figure IB) or circling streaks of compression wood from pith to bark (Figure IC). Also, very infrequent were disks with very little compression wood development (Figure ID).

The azimuth or bearing of arcs of compression wood formed at the 2 m stem height were measured for all the trees sampled at the 4 plantations. Compression wood found within a radius of 2.5 cm from the pith was not included to avoid much of the crown-influenced growth. Percentages of trees having compression wood by 30 degree segments of the compass from 0 to 360 degrees were calculated. These are shown in Figure 2 for each of the plantations. Plots of amount and direction of tree lean, aspect of slope, and direction of prevailing winds are also given. (Note: many trees have compression wood in arcs of 180 degrees and more, percentage frequencies merely show counts of trees with compression wood falling within each 30 degree segment.)

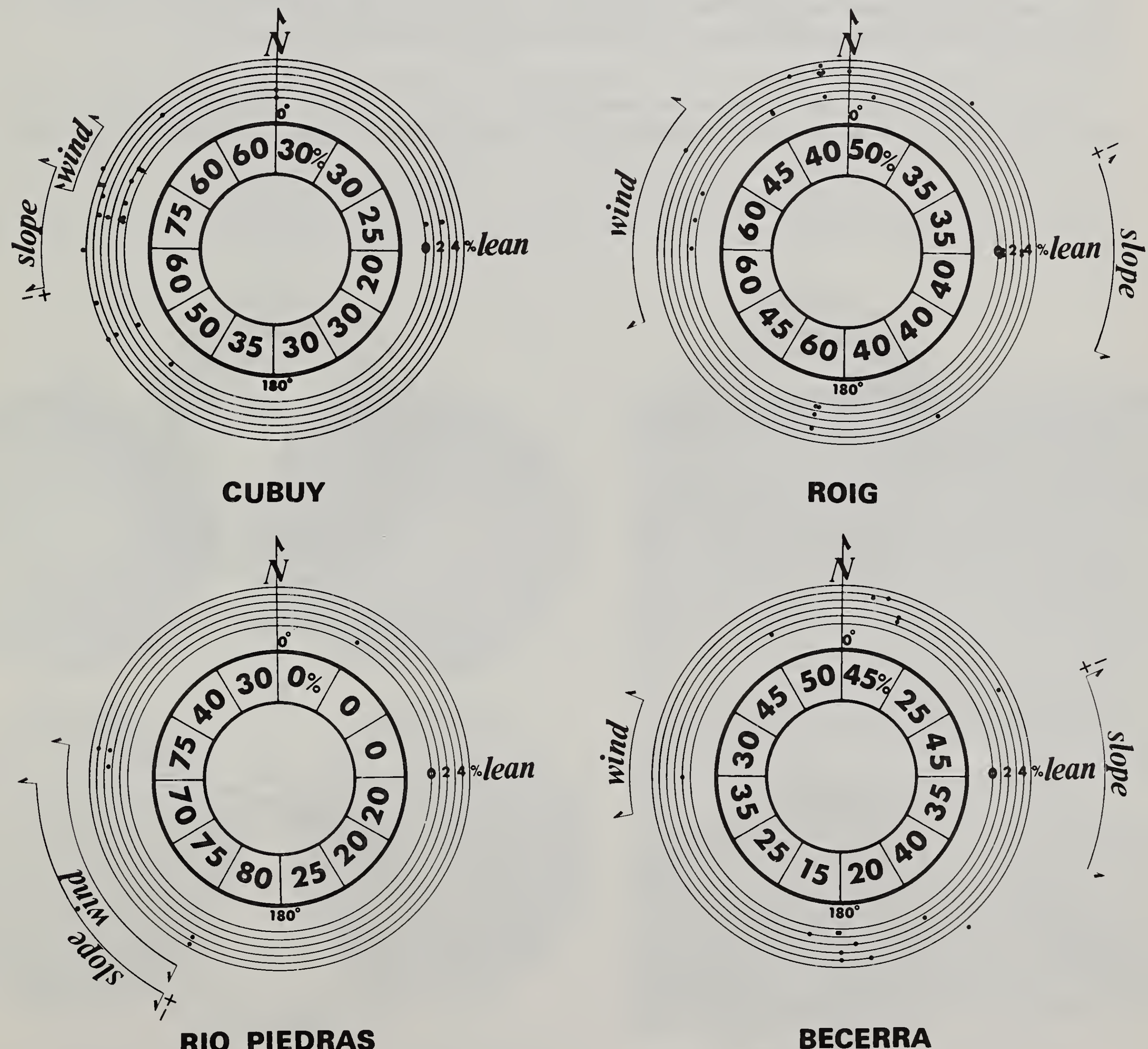

Figure 2. – Orientation of compression wood for each plantation; 2 meter height. Percent of trees with compression wood formed for each 30 degree compass segment is shown by bold type in inner circle. Direction and amount of tree lean is indicated by location of dots in outer circles. Prevailing wind and aspect of downhill slope are also shown.

Some 50 to 70 percent of the trees sampled at the Cubuy plantation have compression wood located between an azimuth of 240 and 310 degrees. Most of the trees lean in this direction. Figure 2 also shows the coincidence of aspect of slope and prevailing wind. The few trees tested at the Rio Piedras plantation, somewhat similarly, have 70-80 percent of the trees with compression wood between azimuths of 210 and 300 degrees. Again this agrees nicely with lean, prevailing wind, and aspect of slope. In contrast, compression wood patterns in trees from the Becerra and Roig plantations are not strongly oriented in any particular direction. Bearings of tree lean are well distributed around the compass and aspect of slope and direction of prevailing winds are, respectively, almost due east and due west. It appears, then, that when wind and slope "pull" together there is a bunching of compression wood in that direction. Though half of the sample trees at Cubuy had little or no lean ($\leq$ 1 degree), compression wood was mostly leeward and on the downhill side of the stems. Low (12) found that prevailing winds in Scotland influenced lean of trees and, therefore, location of compression wood and believed influence of wind overrode that of slope.

Plots of percentages of trees having compression wood in the 30 degree segments around the compass at 2, 4, 6, and 8 m heights in the Cubuy trees are given in Figure 3. As stated

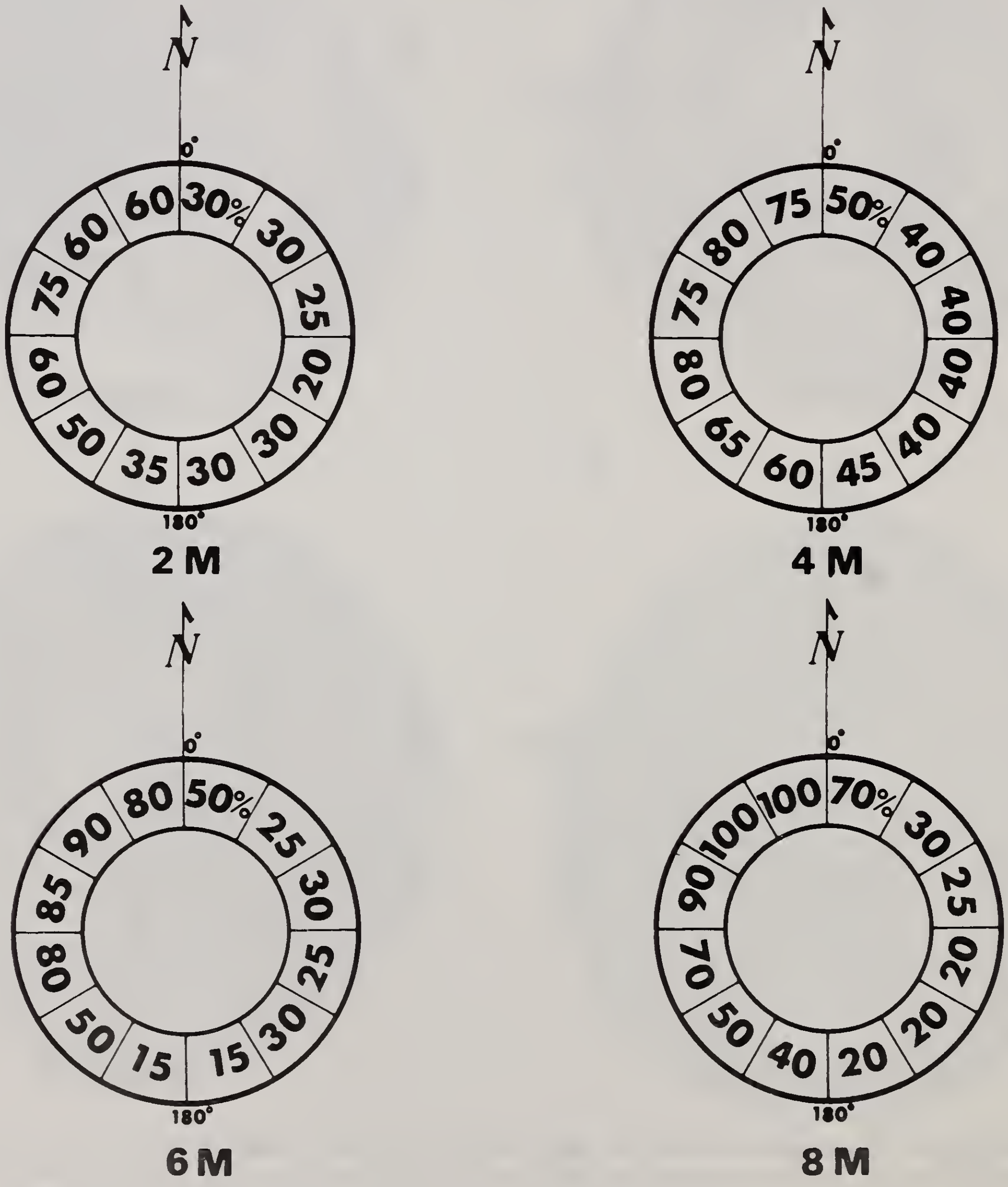

Figure 3. – Compression wood orientation patterns in Cubuy Plantation stems at various heights. Percent of trees with compression wood formed at each 30 degree compass segment is shown for 2, 4, 6, and 8 meter stem heights.

above, at the 2 m height 50 to 70 percent of the trees have compression wood between an azimuth of 240 and 310 degrees. At the 4 m level, 80 percent of the trees have compression wood concentrated in an arc from 270 to 330 degrees. Further up the stem at the 6 m height, 90 percent of the trees have compression wood in this same arc. At the 8 m height, all of the Cubuy trees have compression wood oriented from 300 to about 360 degrees. From the stump towards the top of the trees, there is an increasing concentration of compression wood and a shifting of orientation in a counterclockwise direction (looking upward towards the crown). This drift has been reported for other coniferous species (11, 14, 19).

Growth Rings-False Rings

Cross-section disks used to measure compression wood were also used to observe ring patterns. This ranged from all "earlywood" growth with no or obscure rings to many rows of thick-walled cells forming broad and distinct rings (Figure 4). Figures 4A and 4B show stems with an all "earlywood" inner core. These are about 5-7 cm in diameter and generally represent the first 3 years of growth. Subsequently, there is the usual Temperate Zone "earlywood"-"latewood" target pattern. The quoted seasonal terms are used only for convenience and refer to cell type rather than time of year. The broad and distinct rings may be interspersed with a profusion of false or multiple annual rings (Figure 4A). This is more clearly shown in Figure 5. "Earlywood" type growth may also persist for about 5 years (Figure 4C) or 8 years (Figure 4D) and only then does a weak but distinct ring begin to form.

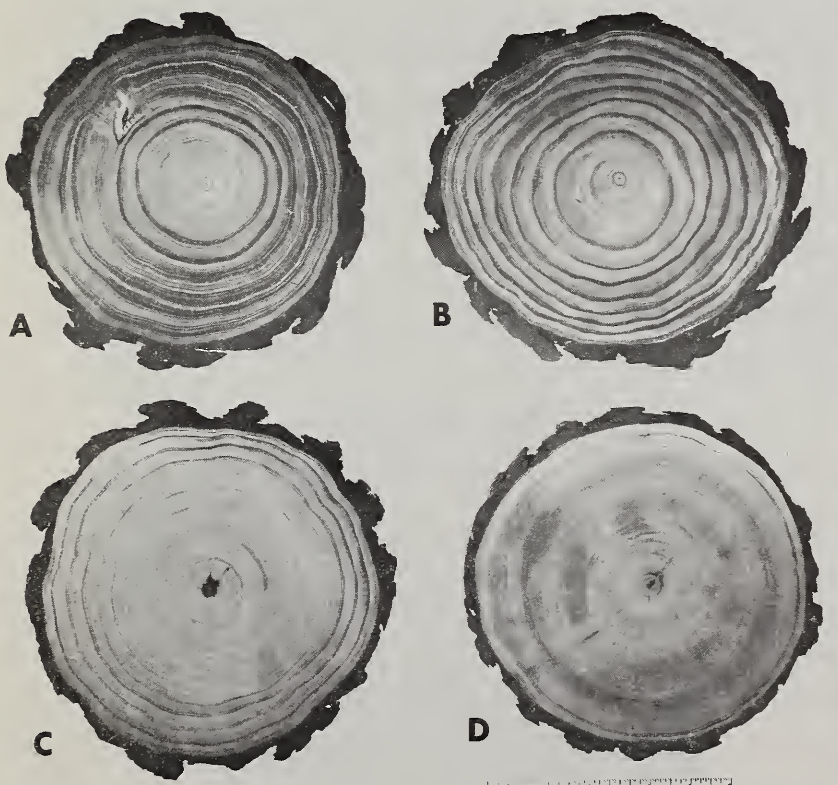

Figure 4. – Ring patterns in plantation-grown *Pinus caribaea:* (A) all "earlywood" inner core followed by broad distinct bands of "latewood" interspersed with false ring; (B) similar to (A) but with few or no false rings; (C) persistence of all "earlywood" growth with some weak but distinct ring formation; (D) 8 years of "earlywood" growth, 1 weak ring near bark.

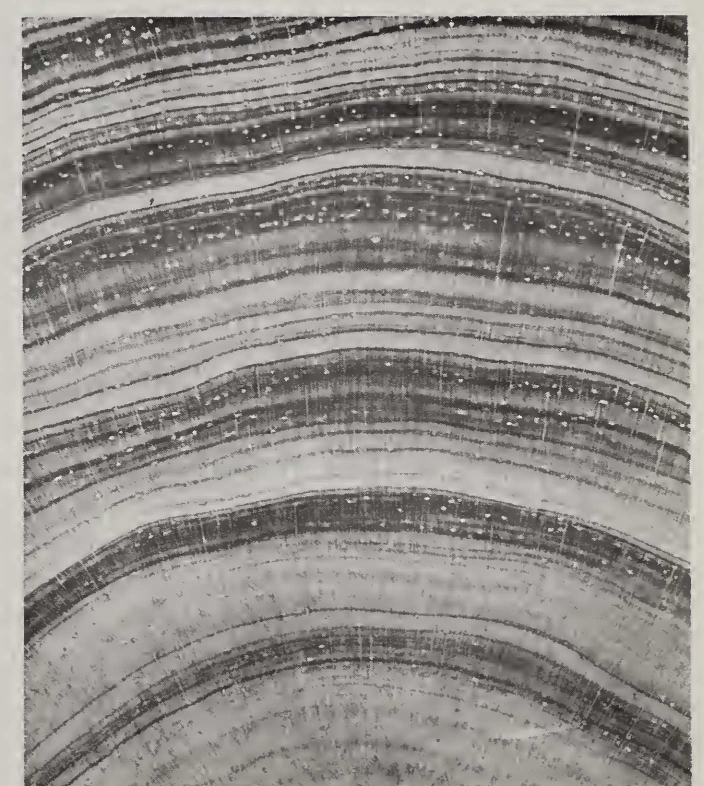

Figure 5. – Enlargement of portion of Figure 4A showing detail of rhythm of false ring formation.

There is some consistency in ring formation within each of the plantations sampled. "Latewood" bands, when formed at the Cubuy plantation, are only a few cells wide and appear to be annual. Growth rings at the Becerra plantation are more conspicuous with "latewood" 100-125 cells wide. These two plantations are in the Subtropical Wet Life Zone (5). The Roig and Rio Piedras sites are Subtropical Moist (5) and here there are not only well formed annual rings but also a consistent inclusion of about 6 false rings. Patterns of growth and physiology of wood formation in *Pinus* has been discussed in detail by Larson (9) and inner core "earlywood" tracheid patterns may be foliar or crown induced. Also, the rhythmical pulsing of false rings is surely in harmony with frequent shoot flushes. However, we cannot describe what components in the two adjacent and closely related life zones are stimulating these differences in growth.

Physical and Mechanical Properties of Compression Wood

Density and shrinkage

Measurements to show the effect of compression wood on specific gravity and shrinkage were made using a matrix of wood growth that is 10 years old or less. Dadswell (4) described changes in tracheid length, fibril angle, shrinkage, and density from the pith outward. From plots of the magnitude of these variables with the number of growth rings from the pith, he defined the immature or juvenile stage of *P. radiata* to be 12-15 years. For other pine species, it may be 20 years or more. Age limits for juvenile wood in fast-grown *P. caribaea* has not been defined but will probably be similar to *P. radiata.*

Basic specific gravities (oven-dry weight/green volume) and green to oven-dry shrinkages for the Cubuy plantation material, having several levels of compression wood, are given in Table 3. Non-extracted specific gravity for test specimens with 10 percent or less compression wood is 0.35. As the volume of compression wood increases to 50 percent or more, there is no significant change in weight. The fast-grown immature wood of *P. caribaea* is similar in weight to slow forest-grown *P. strobus* and *P. lambertiana* but about 50 percent lighter than mature native growth of *P. caribaea* in British Honduras (Table 3).

High fibril angle in the S_2 layer of the secondary wall in tracheids has long been associated with the high longitudinal shrinkage of compression wood (3, 11, 14, 19). This is clearly demonstrated in Table 3. Where compression wood makes up 10 percent or less of the specimen volume, longitudinal shrinkage is only 0.15 percent. For each increase in level of compression wood content, there is an increase in shrinkage. Maximum shrinkages of 0.88 percent are in those woods with 50 percent or more high fibril angle tissue. A linear regression analysis shows this to be highly significant. Also, because of this high fibril angle in compression wood, there are decreases in radial, tangential, and volumetric shrinkage with increases in compression wood content. The shrinkage values for test specimens with little or no compression wood (10 percent or less) are almost identical with those for the low density pines in Table 3, but are much lower than the values for forest-grown *P. caribaea.*

Strength as a beam

Modulus of rupture, modulus of elasticity, and work to maximum load were calculated for the static bending beams tested at 12 percent moisture content. These values for the several levels of compression wood, as well as oven-dry weight and volume specific gravities, are given in Table 4. Bending strength or modulus of rupture varies but slightly with levels of compression wood and agrees closely with that of forest-grown pines of the same density.

Modulus of elasticity or stiffness, however, has highly significant decreases with increases in levels of compression wood. From a value of 920,000 psi for wood with 10 percent or less compression wood, there is a drop to 700,000 psi for beams with the highest presence of compression wood (50 percent and over). The beams with the lowest level of compression wood have a stiffness value about 25 percent lower than that for *P. strobus* or *P. lambertiana.* Those beams with high levels of compression wood are 40-50 percent lower in stiffness. Large reductions in modulus of elasticity due to presence of compression wood was demonstrated by Pillow and Luxford (14). Work to maximum load values, however, do not appear to vary with compression wood content and at any level are almost double those for the low density forest-grown pines. This is not due to the comparison of 2 by 2 in. beams with our 1 by 1 in. beams for Pillow and Luxford (14) also show about 50 percent gains over normal wood in work to maximum load values of *P. taeda* containing compression wood. All of the air-dry beams failed abruptly during test with brash fractures. Work to maximum load values in Table 4, then, are almost identical to those for total work. Forest-grown *P. caribaea* is almost twice as dense as the plantation-grown wood and all static bending values are also considerably higher (Table 4).

Seasoning and machining

Seasoning involved air drying rough, flat-sawn, 1-in. boards from green moisture contents well over 200 percent to a moisture content of 18-20 percent and then kiln drying to 10 percent. None of the 77 random width (3-7 in.) 6-ft. boards showed any degrading surface checks, end-splits, or cross breaks after drying. Boards were also examined for warp with the following results: *cup...* 60 percent of the boards rated as light, 40 percent as medium to heavy; *twist...* 93 percent rated as light, 7 percent as medium to heavy; *bow...* all boards rated as light to medium. Gradings are those for southern pine lumber (17) and most of these test boards meet warp limitations of "C" finish and all meet the No. 1 board specifications. This remarkable freedom from seasoning degrade is contrary to the general performance of lumber streaked with compression wood.

Though not a formal part of this study, the dried boards were then planed on two sides. The surfaces dressed well with little or no raised, torn, or fuzzy grain regardless of presence of compression wood (Figure 6). Edges were patterned with a tongue and groove on a single-spindle shaper and boards were used to panel a concrete wall. Some two years after installation, there has been no discernible movement or warping in place.

Figure 6. — Flat sawn boards of *Pinus caribaea* with no compression wood (A), oriented along one edga (B), and across the full width (C) after planing and showing smoothness of cut.

CONCLUSIONS

From this study of compression wood formation in 8 to 10 year old plantation-grown *P. caribaea,* we may conclude the following:

1. Compression wood was found in all 71 trees sampled from four plantations.

2. At the intensively investigated Cubuy plantation, the amount of compression wood formed was not related to height in the tree.

3. There may be a significant interaction of lean, growth rate and slope of terrain in the formation of compression wood.

4. The amount of compression wood generated at the Cubuy plantation was significantly higher than that at Roig and Becerra but no different than that found at Rio Piedras.

5. Orientation of compression wood in stems did take place when direction of tree lean, aspect of slope, and direction of prevailing wind coincide.

6. From the stump towards the top of the trees, there was an increasing concentration of compression wood and a shifting of orientation in a counterclockwise direction.

7. Patterns of growth ring formation ranged from all "earlywood" tracheids to broad conspicuous bands of "latewood" interspersed with many false rings.

8. Specific gravity of *P. caribaea* did not vary with intensity of compression wood formation but is about 50 percent lighter than when forest-grown in British Honduras.

9. Longitudinal shrinkage increased and radial, tangential and volumetric shrinkage decreased with increasing content of compression wood.

10. Modulus of rupture and work to maximum load did not vary with increasing levels of compression wood. Modulus of elasticity or stiffness, however, was very sensitive to presence of compression wood and may be reduced considerably. Bending strength and work values compared favorably with forest-grown wood of the same density.

11. Though streaked with high volumes of compression wood, 1-in. boards were dried from green to 10 percent moisture content with no checking, cross-breaks, or serious warp.

12. Compression wood boards machined well to yield smooth-surfaced panels that have been in service for more than two years with no discernible movement or warp.

TABLE 1.--TREE AND SITE DESCRIPTION OF *PINUS CARIBAEA* SAMPLED.

Plantation	Trees sampled			Site	
	Age[1/]	No.	D.b.h. range	Elevation	Life zone[2/]
	Yrs.		cm	m	
Cubuy	8	24	11.9 - 26.2	480	Subtropical wet
Becerra	10	16	11.7 - 35.0	820	Subtropical wet
Roig	9	25	10.0 - 21.5	110	Subtropical moist
Rio Piedras	8	6	11.9 - 17.0	30	Subtropical moist

1/ Age at time of sampling.

2/ After Holdridge (5).

TABLE 2.--PERCENT AREAS OF COMPRESSION WOOD IN *PINUS CARIBAEA* AT CUBUY.

Height in tree	Tree lean $\leq$ 1 degree				Tree lean $\geq$ 2.5 degrees				Mean All trees
	Fast grown		Slow grown		Fast grown		Slow grown		
	Level	Steep	Level	Steep	Level	Steep	Level	Steep	
m	pct.	pct.	pct.	pct.	pct.	pct.	pct.	pct.	pct.
0	22.7[1/]	24.7	23.0	23.0	13.0	9.7	6.0	23.0	18.1
2	17.0	23.7	20.3	19.0	19.7	23.7	5.7	24.3	18.2
4	20.0	18.3	20.0	22.0	17.0	15.3	9.0	19.3	17.6
6	25.5**	24.3	13.0**	28.3	15.0	17.7	17.0	24.7	19.9
8	22.5**	22.3	23.0**	25.5**	14.5**	16.3	9.0*	21.0*	19.8
10	13.5**	18.0	--	28.0*	23.5**	13.0	--	22.0*	18.1

1/ Each value is mean of 3 trees except double asterisk notes a sampling of 2 trees and a single asterisk a sampling of 1 tree.

TABLE 3.--SPECIFIC GRAVITY AND SHRINKAGE VALUES FOR PLANTATION-GROWN *PINUS CARIBAEA* WITH SEVERAL LEVELS OF COMPRESSION WOOD AND COMPARISON WITH FOREST-GROWN PINES.

Levels of compression wood	Sample size	Basic[1/] specific gravity	Shrinkage (green to oven-dry) radial	tangential	longitudinal	volumetric
pct.	No.		pct.	pct.	pct.	pct.
CUBUY PLANTATION						
0-10	37	.35	2.8	5.5	.15	8.1
11-30	13	.36	2.4	5.4	.24	7.7
31-50	15	.37	2.2	4.2	.52	7.1
51+	6	.37	1.4	3.3	.88	6.0
FOREST-GROWN PINES						
Eastern White Pine *P. strobus* (18)		.34	2.3	6.0	--	8.2
Sugar Pine *P. lambertiana* (18)		.35	2.9	5.6	--	7.9
Caribbean Pine *P. caribaea* (10)		.68	6.3	7.8	--	12.9

1/ Based on oven-dry weight/green volume.

TABLE 4.--STATIC BENDING STRENGTH OF PLANTATION-GROWN *PINUS CARIBAEA* WITH SEVERAL LEVELS OF COMPRESSION WOOD AND COMPARISON WITH FOREST-GROWN PINES.

Levels of compression wood	Sample size	Specific[1/] gravity	Static bending[2/] Modulus of rupture	Static bending[2/] Modulus of elasticity	Static bending[2/] Work to maximum load
pct.	No.		psi	1000 psi	in.-lb./in.^{3}
		CUBUY PLANTATION			
0-10	49	.38	8830	920	11.1
11-30	38	.39	8500	880	9.8
31-50	24	.41	8670	820	10.3
50+	15	.41	8750	700	12.1
		FOREST-GROWN PINES			
Eastern White Pine *P. strobus* (18)		.37	8800	1280	6.7
Sugar Pine *P. lambertiana* (18)		.38	8000	1200	5.5
Caribbean Pine *P. caribaea* (10)		.78	16690	2240	17.3

1/ Based on oven-dry weight and volume.

2/ Tested at 12 percent moisture content.

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